Analysis of Water and Nutrient Budgets
for the Caloosahatchee Watershed

EVALUATION OF AVAILABLE HYDROLOGIC DATA FOR THE CALOOSAHATCHEE WATERSHED

Revised Deliverable for Task 3 of Work Order #1
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EXECUTIVE SUMMARY

Hydrologic data were collected from the South Florida Water Management District (SFWMD), National Oceanic and Atmospheric Administration (NOAA), and U. S. Geological Survey (USGS) for the Caloosahatchee region. The SFWMD has obtained all of the available data from USGS through a cooperative data exchange agreement. Weather data have been purchased by SFWMD from NOAA. Because the available weather station coverage is sparse, data were collected for sites outside the Caloosahatchee watershed to include weather stations and ground water wells that can be used to describe conditions within the Caloosahatchee watershed.

The hydrologic data include weather, surface discharge, water use pumpage, and groundwater stage. The weather data include rainfall, temperature, wind, solar radiation, evaporation and humidity data where available. Complete weather data are available for three sites in the region: Clewiston, S78, and Big Cypress Reservation. Long-term rainfall data are available from many sites in the watershed. The data in this report are restricted to those sites that have more than 16 years on record or have hourly rainfall values. The long period of record is necessary for model simulation and the hourly data are necessary to develop the daily rainfall pattern.

Surface discharge was obtained from USGS through the SFWMD for the primary discharge structures on the canals of the Central and South Florida Flood Control Project. Discharge data was not available for selected private structures on the primary canals.

Groundwater stage data were collected for the surficial aquifer system and the Tamiami aquifer. This aquifer interacts directly with surface water and is necessary to understand surface discharge.

The hydrologic data have been summarized in this report. The data are provided in several formats on the website (http:www.imok.ufl.edu). Although it was intended that these data be developed into a relational database, there has been no agreement among the many potential users concerning the structure or content of the database, nor has there been agreement on the appropriate software. As a result, the data are provided in flat (ASCII) files, and Excel spreadsheets.

1. INTRODUCTION

Water management in the Caloosahatchee Watershed has become an important issue as demand for water by agriculture, the urban sector, and the environment have increased. The watershed is undergoing rapid urban development and there is a greater need for water. At the same time, development and environmental needs on Florida's lower east coast may reduce the supplemental water available from the Lake Okeechobee. Agriculture depends on water released from Lake Okeechobee for irrigation during the dry season. In the future, it will be necessary to fully utilize the available water in the Caloosahatchee Watershed. The requires an assessment of the watershed resources.

One of the important components of a watershed assessment is the evaluation of available hydrologic data. These data are necessary for development of water and nutrient budgets for the watershed. These data are also necessary for determining the impact of alternative land and water management practices on water use and runoff. The primary approach for evaluating alternative practices is through hydrologic simulation.

This report includes the results of the search for hydrologic data pertinent to development of hydrologic models. Compilation of hydrologic data is necessary for calibration and utilization of hydrologic models and development of the water and nutrient budgets. These data include weather data, tributary discharge, Caloosahatchee River (C-43) discharge, groundwater stage, and pumpage values for various structures in the watershed. These data often exist as time series for varying periods of record. Only data available in digital form for long periods were collected in this task. Hydrologic data with short periods of record are difficult to use in hydrologic analysis because they don't contain sufficient climatic variability with which to assess the impact of alternative management practices. Where the data are not available in digital form, they are not included in this report. Where possible, these data include the results from earlier studies.

2. DATA COLLECTION

Hydrologic data were collected through the South Florida Wter Management District (SFWMD) from National Oceanic and Atmospheric Administration (NOAA), U.S. Geologic Survey (USGS), and the water control districts (Chapter 298 special taxing districts). The SFWMD maintains many monitoring sites in the region. The SFWMD has purchased rain, wind, and temperature data from NOAA selected stations in the Caloosahatchee watershed: Clewiston, Ft. Myers, Punta Gorda, and Immokalee. The SFWMD also acquires monitoring data from USGS through a cooperative data exchange program. The SFWMD acquires rainfall data from selected water control districts through cooperative agreements or as part of special conditions on permits.

The set of primary parameter values and time series data necessary for hydrologic simulation will be compiled into a simple database which is well-documented, and efficient for use by personal computer or Unix system. Most of the data will be maintained in flat-files (ASCII) for ease of conversion for selected computer programs. This type of database format will allow revisions to be made to the subbasin-specific primary data as new data become available.

3. HYDROLOGIC DATA

3.1 Weather Data

3.1.1 Hourly Weather Data

Detailed weather information is necessary for developing good estimates of potential evapotranspiration, predicting crop growth, insect vector dispersion, and freeze prediction. Each of these data sets influence water and agrochemical use in the watershed. Detailed weather data are necessary for development and calibration of evapotranspiration models. In particular, net radiation, relative humidity, and wind speed are necessary data. Unfortunately there are few sites in south Florida where detailed weather data have been collected over a long period of time suitable for conducting long-term hydrologic simulations. There are complete data sets for West Palm Beach and Miami. There are not long term records for southwest Florida. The System-wide Hydrologic Modeling Group at SFWMD supplements those data with temperature and wind data from this area for predicting potential evapotranspiration within the Caloosahatchee Watershed.

Weather data were obtain from the SFWMD for both SFWMD sites and NOAA sites. No other data were found. There were three sites for complete weather data in the region (Fig. 1). Of these sites weather data were obtained for three sites: Clewiston Field Station, Big Cypress Indian Reservation, and Ortona Locks. The data were collected at 15 minute intervals and recorded on CR-10 data loggers. Data collection at these sites began in 1992 and continues to present. The weather data collected at the selected stations are given in Table 1 and typical data are presented in Figures 2-4.

Fig. 2. Typical hourly weather data: Ortona Locks May 1993

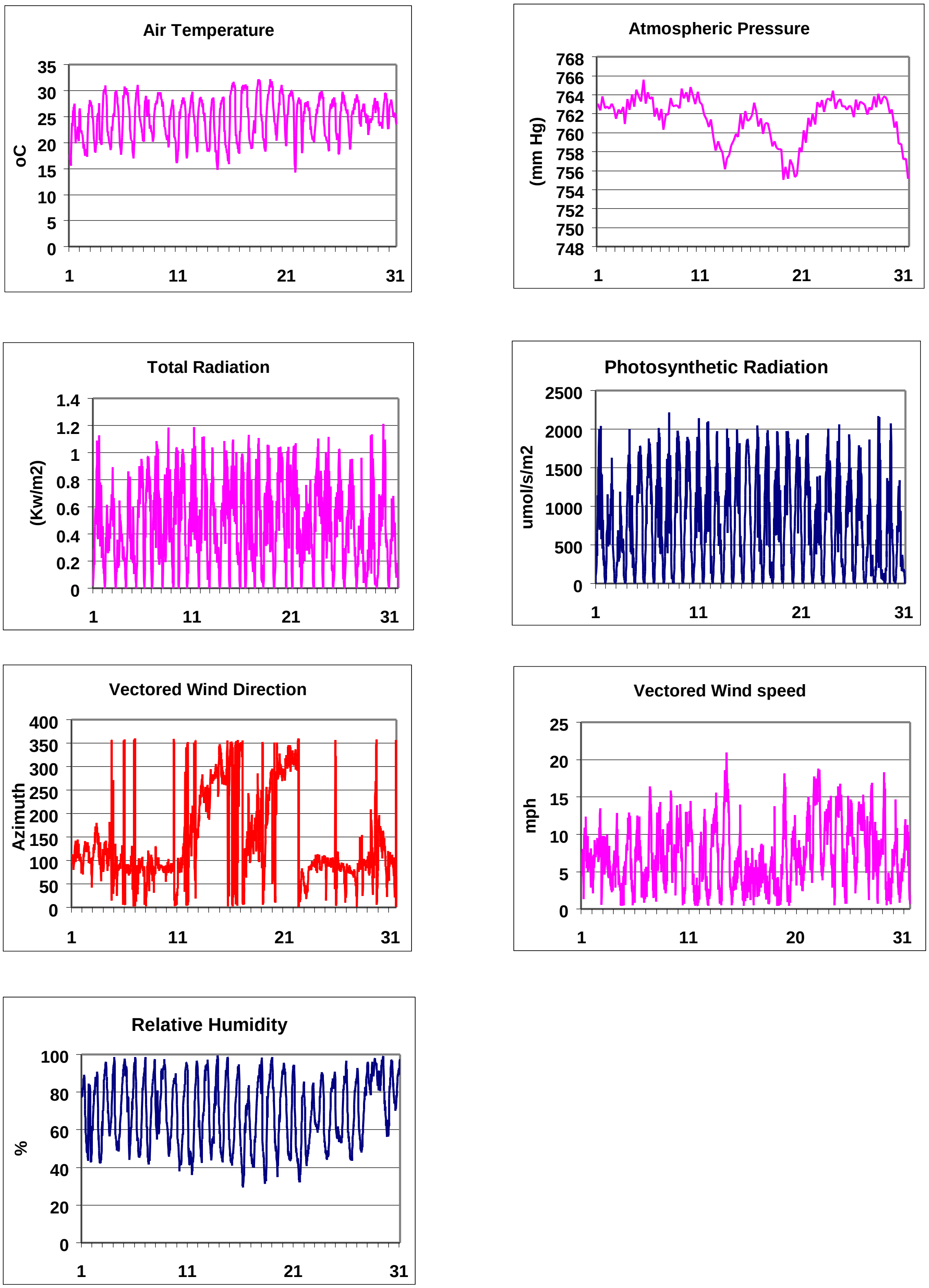


Fig. 3. Typical hourly weather data: Big Cypress Reservation - May 1993

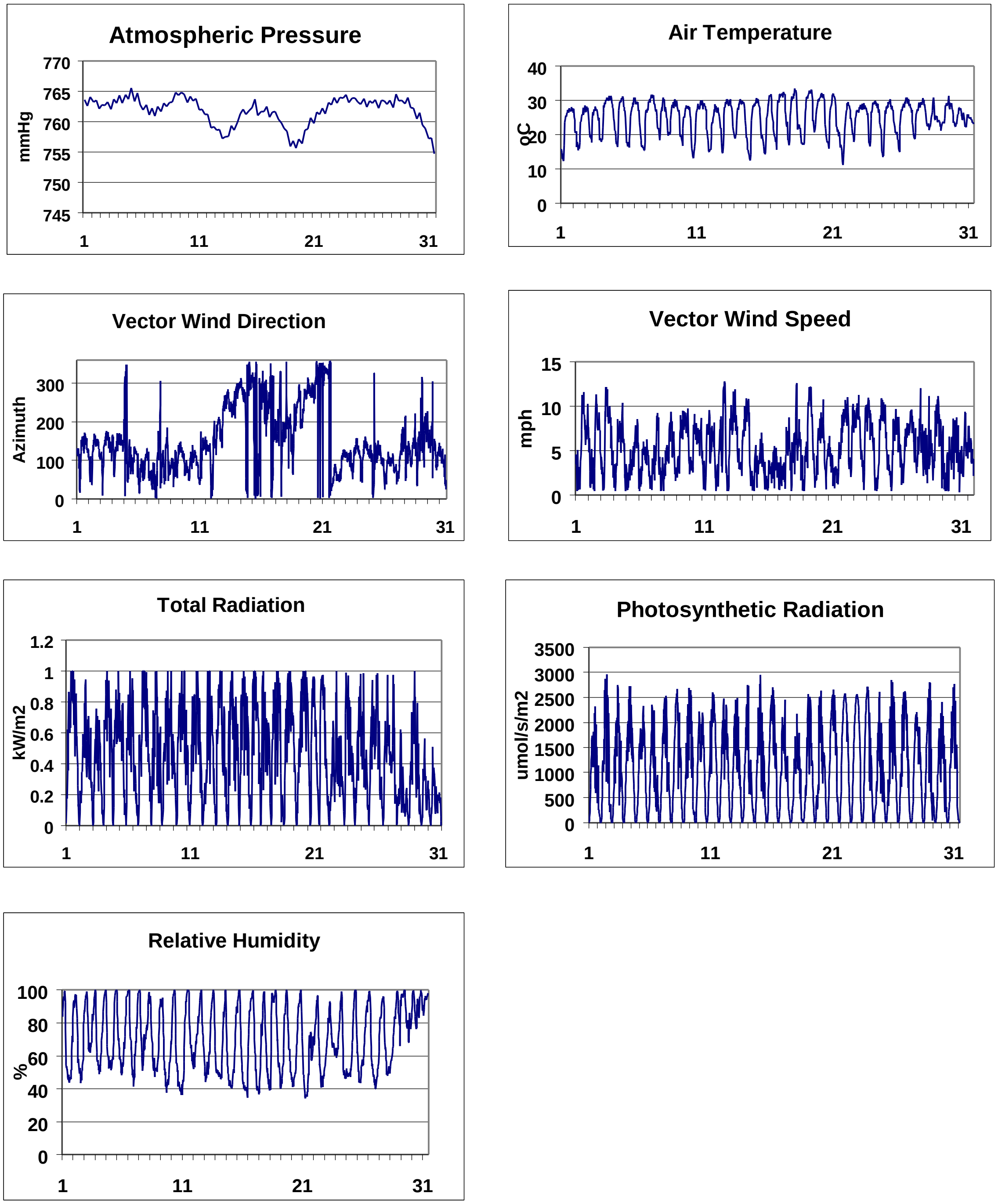


Fig 4. Typical hourly weather data: Clewiston Field Station - May 1993

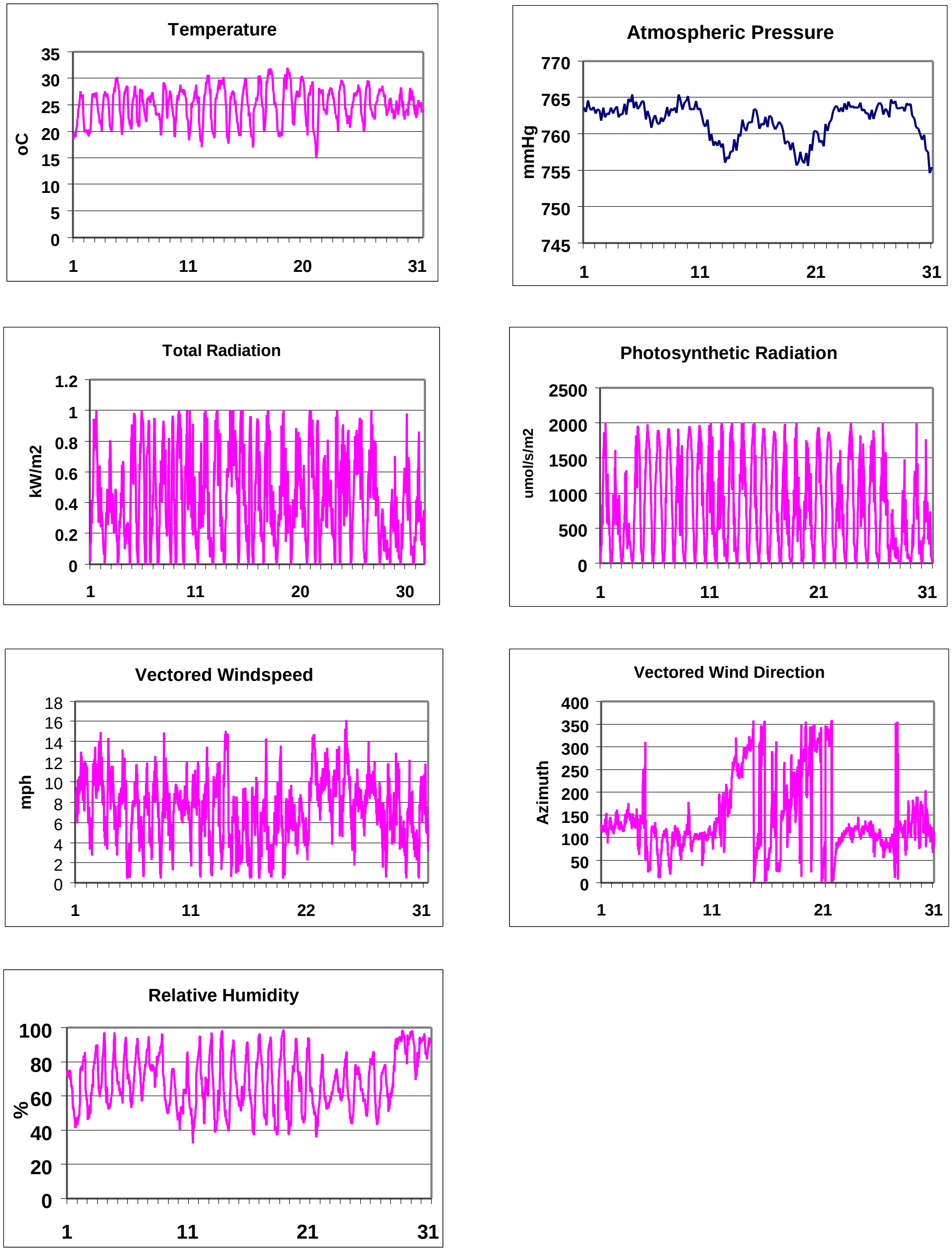


Table 1. Weather data for selected parameters in the Caloosahatchee Region.

Measurement	Equipment
Air Temperature (AT)	Vaisala HMP35C temperature and humidity probe
Relative Humidity (RH)	
Barometric Pressure(AP)	Vaisala PTA427 pressure transducer
Photo-active Radiation (RP)	LI-COR LI190SZ Quantum
Total Radiation (RT)	LI-COR LI1200SZ pyranometer
Vector Wind Speed (VS)	Qualimetrics Skyvane Model 2100
Vector Wind Direction (VD)	

3.1.2 Hourly Rainfall

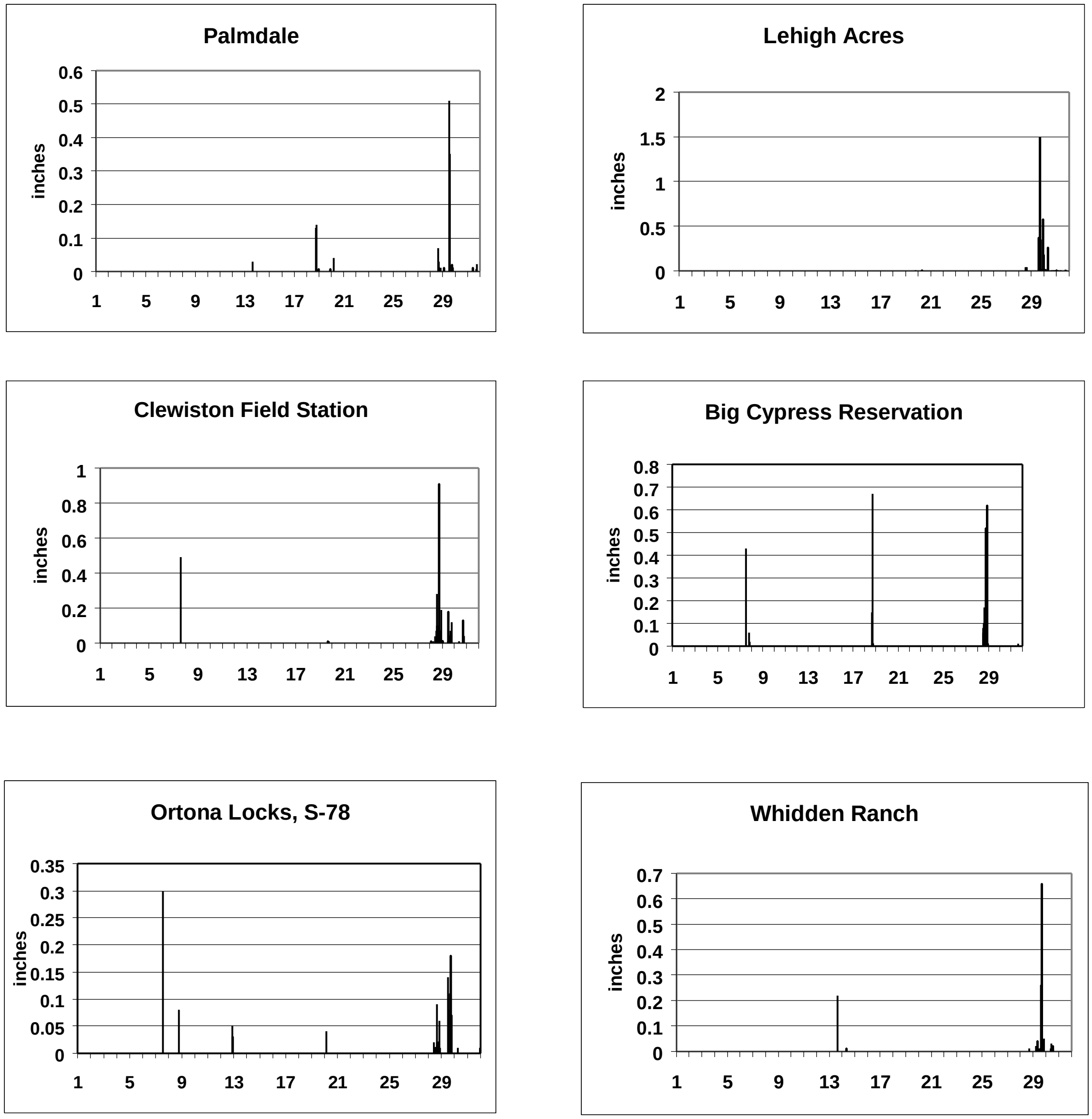
Several hydrologic simulation models require hourly rainfall in order to calculate daily runoff. The models are useful for simulating nutrient transport. Hourly rainfall is not commonly measured. It is only available at selected locations; West Palm Beach, Miami, and Okeechobee for long periods of record. In the past, hourly rainfall was quantified by digitizing stripcharts from weighing raingages. This was time consuming and limited the amount and quality of available data. Recently, tipping bucket raingages have been connected to electronic data loggers which can provide an accurate rainfall record at high temporal resolution.

There are six hourly rainfall gages in the Caloosahatchee Region (Fig. 1). Data are available at these sites from 1992 to present (Table 2). Typical data for these sites are presented in Fig. 5 for May 1993. As indicated in the Figure 5, there is a substantial variability in rainfall within the watershed. Hourly precipitation rates vary from 0.2 to 1.5 in. hr^{-1} within the a storm. There also is considerable difference in the rainfall pattern within a single storm among the stations.

Table 2. Hourly rainfall sites for the Caloosahatchee Region.

Station	Dbkey	Start Date
Big Cypress Indian Res.	15685	10/21/92
Clewiston Field Station	15517	10/21/92
Lehigh	15464	11/1/92
Palmdale	15786	4/16/92
S78w	15495	10/21/92
Whidden 3	15465	11/9/92

Fig. 5. Typical hourly rainfall volume for May 1993 for the Caloosahatchee



3.2 Long-term Rainfall

Long-term rainfall data are necessary for conducting three analyses for watershed assessment. The long-term data are used to develop the relationship between rainfall and runoff, and determine how that relationship may have changed following changes in land use. These data are necessary for hydrologic simulation; a short period of record may not provide a sufficiently varied dataset for evaluating alternatives. Finally, the long-term data are used to evaluate the spatial variability in rainfall in the watershed. The spatial variability in rainfall determines how the measured data from the monitoring network are combined to provide areal rainfall estimates.

Long-term daily rainfall volumes were collected for 17 locations (Fig. 1). These data were collected by several agencies; NOAA, SFWMD, US Army Corps of Engineers (COE), and the Florida Department of Forestry (FS) (Table 3). There is a range in length of record beginning with Ft. Myers that began in 1909 to Whidden where collection began in 1982. At most sites, rainfall was collected in a standard can and measured in the morning. Two other sites, Lehigh and Clewiston are not included in this list. At those sites rainfall was recorded only on weekdays and does not present high quality data.

Table 3. Long-term rainfall data in the Caloosahatchee Region.

	Station Location	Station Name	Dbkey	Start year	Source
1	Punta Gorda	PUNTA G4_R	6139	1965	NOAA
2	Alva	ALVA FAR	5922	1968	WMD
3	Corkscrew	CORK.HQ_R	5916	1959	WMD
4	Ft. Myers	FORT MEY_R	6193	1909	NOAA
5	Immokalee	IMMOKA 2_R	6082	1963	FS
	Immokalee	IMMOKA 3_R	6195	1941	NOAA
6	South Lee County	SLEE_R	6081	1969	FS
7	Whidden	WHIDDEN3_R	6555	1982-1990	WMD
	Whidden	WHIDDEN3_R	15465	1992	WMD
8	S131	S131_R	6120	1965	WMD
9	Lake Okeechobee	L OKEE.M_R	5883	1976	WMD
10	Devils Garden	DEVILS_R	6206	1956	WMD
11	Alico	ALICO_R	15197	1973	WMD
12	Keri	KERI TOW_R	6083	1969	FS
13	LaBelle	LA BELLE_R	6158	1929	NOAA
14	S79	S79_R	5899	1940-1987	WMD
	S79	S79_R	7825	1987	WMD
15	S78	S78_R	6243	1940-1991	NOAA
	S78	S78_R	16625	1991	WMD
	S78	S78_R	6221	1968	COE
16	Palmdale	PALMDALE_R	6093	1963	FS

Fig.6 Typical rainfall for long-term raingages in the Caloosahatchee region

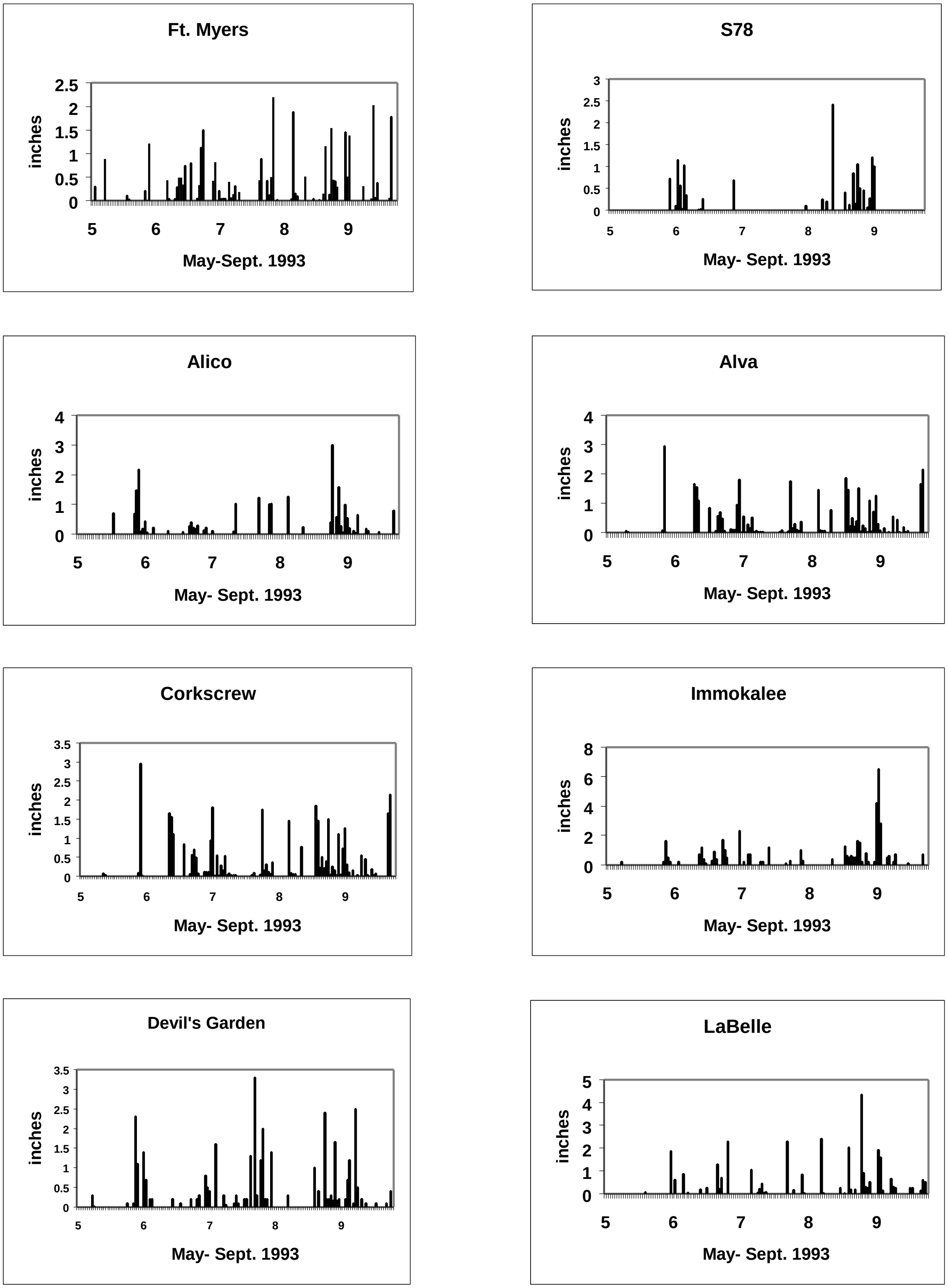
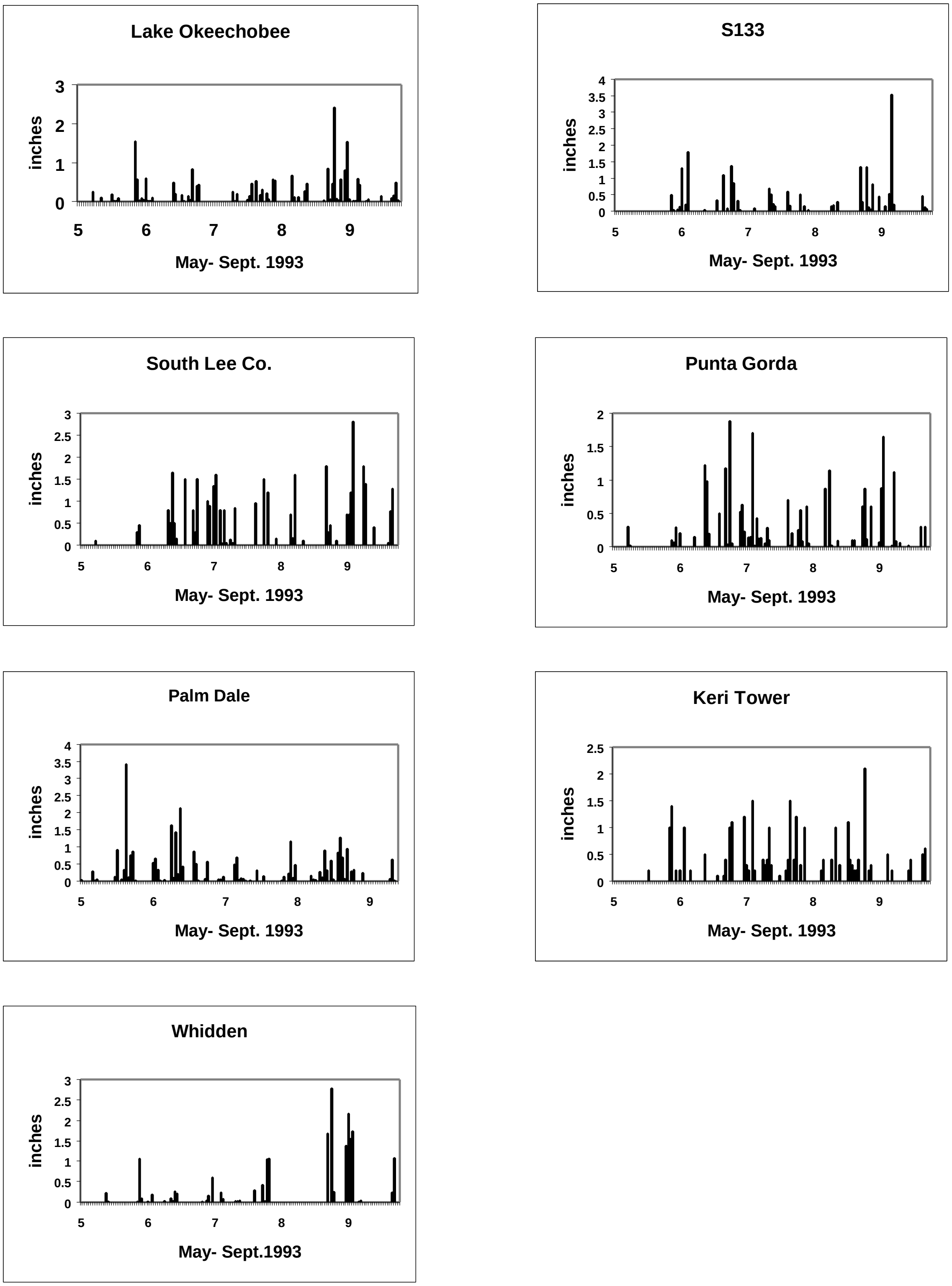


Fig.6 Typical rainfall for long-term raingages in the Caloosahatchee region



Typical daily rainfall records are presented for the period May to September 1993 in Fig. 6. Note the similarity in rainfall patterns at sites that are in close proximity such as S79 and Ft. Myers, compared to inland sites. Also note the variability in rainfall volume.

A set of thiessen polygons were created to apply the rainfall data to the Caloosahatchee watershed (Fig. 7). According to this scheme, all land within each polygon receives the rainfall record from that site. Alternatively, a universal kriging can be use to provide areal estimates of rainfall for each land use parcel. The disadvantage of kriging is that the extreme values in the dataset are lost and replaced by areal average.

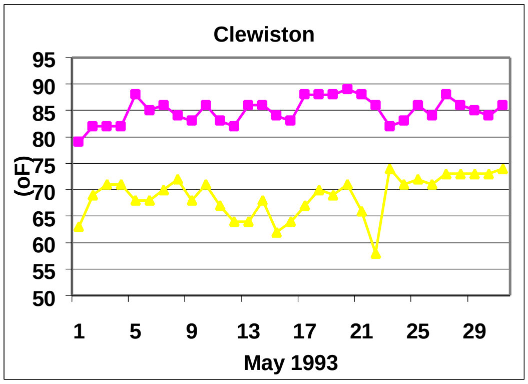
3.1.3 Temperature

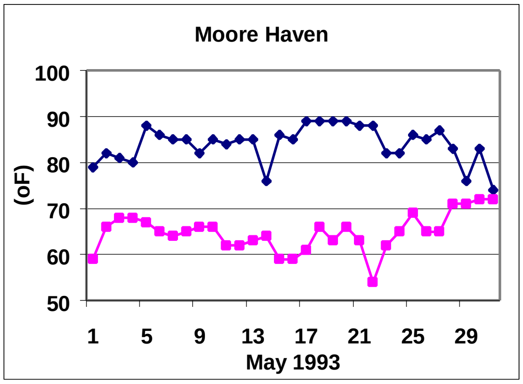
Temperature data are used for estimating evapotranspiration. Daily maximum and minimum temperatures are collected at nine stations in the region (Fig. 8). The District had data from 1931 for Moore Haven, Ft. Myers, and Arcadia (Table 4). Except for Immokalee which starts in 1970 and Archbold which starts in 1969, there is a complete set of data from 1965 to present. Typical values are presented for May 1993 (Fig. 9).

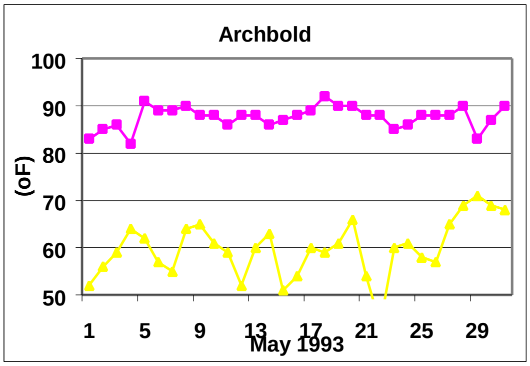
Table 4. Minimum and maximum temperature data for the Caloosahatchee Region.

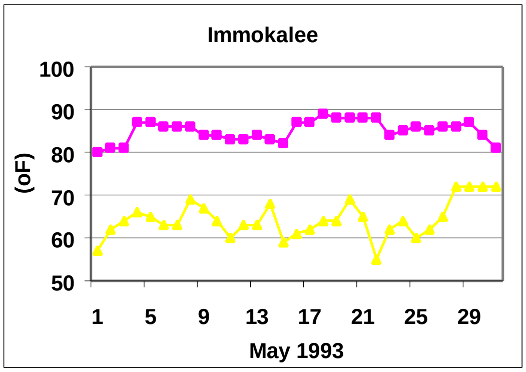
	Station	Start Date
1	Punta Gorda	11/ 1/65
2	Moore Haven	1/ 2/31
3	La Belle	7/ 1/48
4	Immokalee	6/ 1/70
5	Ft. Myers	1/ 1/31
6	Devils Garden	6/ 1/56
7	Clewiston FS	11/1/49
8	Arcadia	1/ 1/31
9	Archbold	1/ 1/69

Fig 9. Typical Daily minimum and maximum temperatures for the Caloosahatchee Region









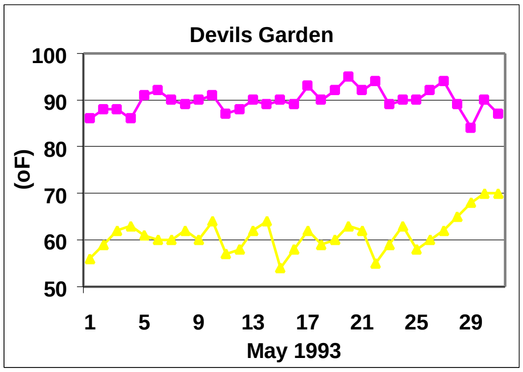
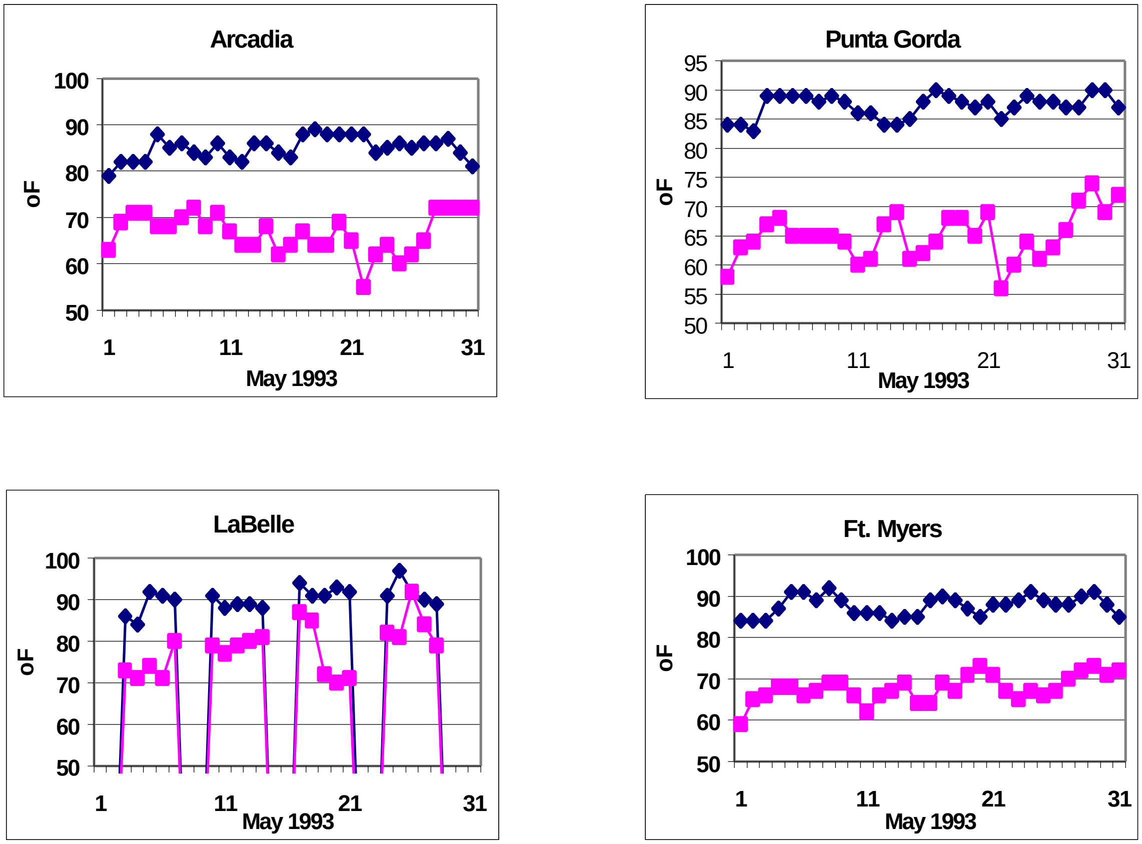


Fig 9. Typical Daily minimum and maximum temperatures for the Caloosahatchee Region



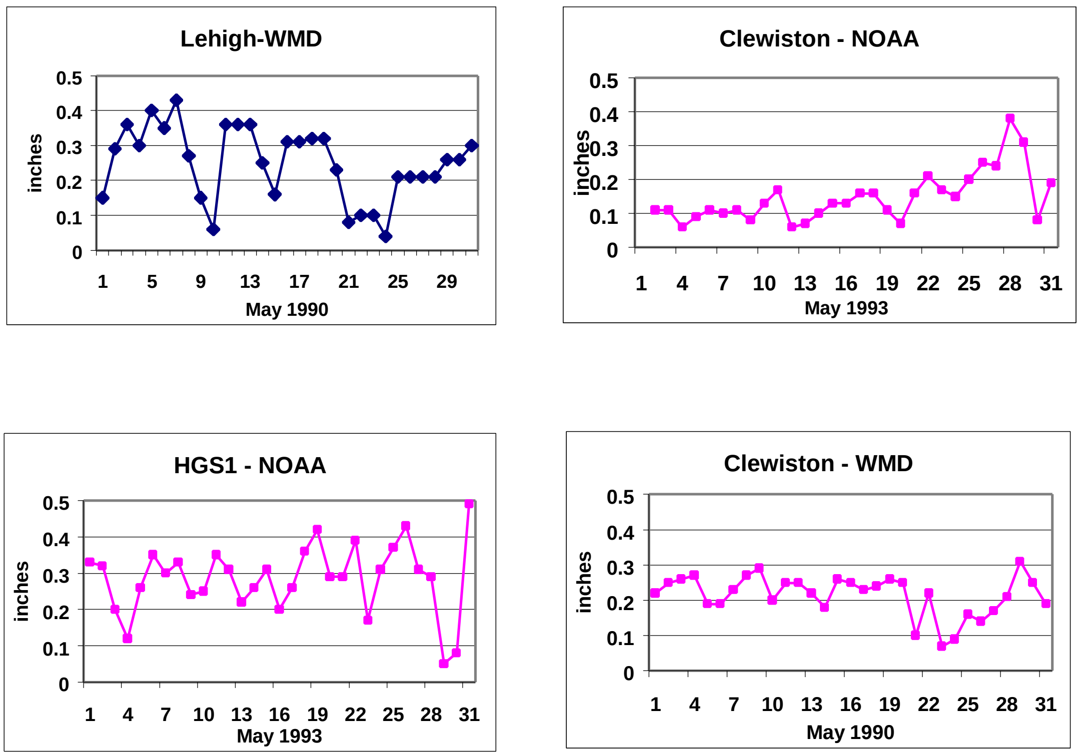
3.1.4 Evaporation Data.

Where weather data are not available for estimating potential evapotranspiration (ET), evaporation pan values provide useful information. These data combined with crop coefficients provide reasonable ET estimates. Evaporation values are available at four sites in the watershed (Fig. 8). At two of these sites the data are collected by NOAA (Clewiston and HGSLE). At the other two sites (Clewiston Field Station and Lehigh) the data were collected by SFWMD (Table 5). Those data are not current but they present a period of record during a period of substantial change in the watershed. Other data were collected at Corkscrew Sanctuary and Palmdale, but for shorter periods. Typical data are presented in Fig. 10. The data from Lehigh were collected only during week days so the Monday values are averaged across the weekend.

Table 5. Evaporation pan data for the Caloosahatchee Region.

Station	Dbkey	Period of Record	Source
Clewiston	6365	1970-97	NOAA
Clewiston F.S.	15208	1983-90	WMD
HGSLE	6381	1948-97	NOAA
Lehigh	6330	1978-90	WMD

Fig. 10 Typical daily evaporation pan values for May.



3.3 Surface Water Discharge

Surface water is monitored at the primary structures on the Caloosahatchee (C-43) and C-19 canals (Fig. 11). The C-43 structures include the lock and spillway structure at Lake Okeechobee (S-77), the gated culverts (S-235) that controls water exchange between the East Caloosahatchee basin and the S-4 basin, the lock and spillway structure at Ortona (S-78), and the Franklin lock and dam structure (S-79) at Olga. The structures on C-19 include S-47d at Lake Hicpochee, S-47b near highway US 27, and S-342 at the terminus in Nicodemus Slough. The flow data have been calculated by the SFWMD and USGS based on COE gate-opening data and upstream and downstream stages

(Table 6). The USGS data have been accepted as the preferred datasets at each structure. The quality of the discharge data is unknown, the USGS had intended to redevelop the stage-discharge curves for each structure. The total monthly discharge for each structure is presented in Fig. 12 along with runoff. Runoff is defined as the discharge from S79 minus the inflow from S-77, S-235, and S-47d. Runoff does not include any regulatory discharge from Lake Okeechobee.

Table 6. Monitored surface water discharge structures in the Caloosahatchee Watershed.

Structure	Description	DBKey	Record	Source
S-77	Lock & Dam	853		USGS**
		15016	1963 - 90	WMD
		15635	1972 - 97	WMD
S-235	Gated Culverts	4214	1975 - 90	WMD**
		15564	1990 - 97	WMD**
		12815	1988 - 97	WMD
S-47B	Gated Culverts	4326	1978 - 91	WMD
		15944	1995 - 97	WMD
S-47D	Spillway	4376	1975 - 93	WMD
		15578	1993 - 97	WMD
S-342	Culvert	13163	1992 - 97	WMD
S-78	Lock & Dam	857	1971 - 97	USGS**
S-79	Lock & Dam	865	1966 - 96	USGS**
		15045	1963 - 90	WMD

** Preferred data for analysis.

3.4 Groundwater Stage

Groundwater head information is useful for monitoring groundwater usage and local recharge. Head data from the water table aquifer can be used to evaluate the effectiveness of seepage systems and alternative surface water management practices on local groundwater storage. Unfortunately, there are few active wells in the watershed.

There are many groundwater monitoring wells in the Caloosahatchee Watershed. The digital records for 72 groundwater monitoring are available in the SFWMD database. These wells have been used to monitor piezometric head in the water table, lower Tamiami, and Sandstone aquifers. Most of these wells were monitored in the 1970s and 1980s. There are 34 active groundwater stage monitoring wells in the watershed: sixteen wells are in the west Caloosahatchee Basin, three wells are in the Orange River basin, three wells are in flagpole basin, and 11 wells are in the East Caloosahatchee Basin (Fig. 11). Several of the active wells are USGS wells. The typical head data for those wells are presented in Fig. 13 for the May 1994. The remaining wells are part of the SFWMD ambient groundwater monitoring program. The stage data for the period of record for those wells are presented in Fig. 14.

Fig. 12. Total monthly discharge and runoff for major C-43 structures

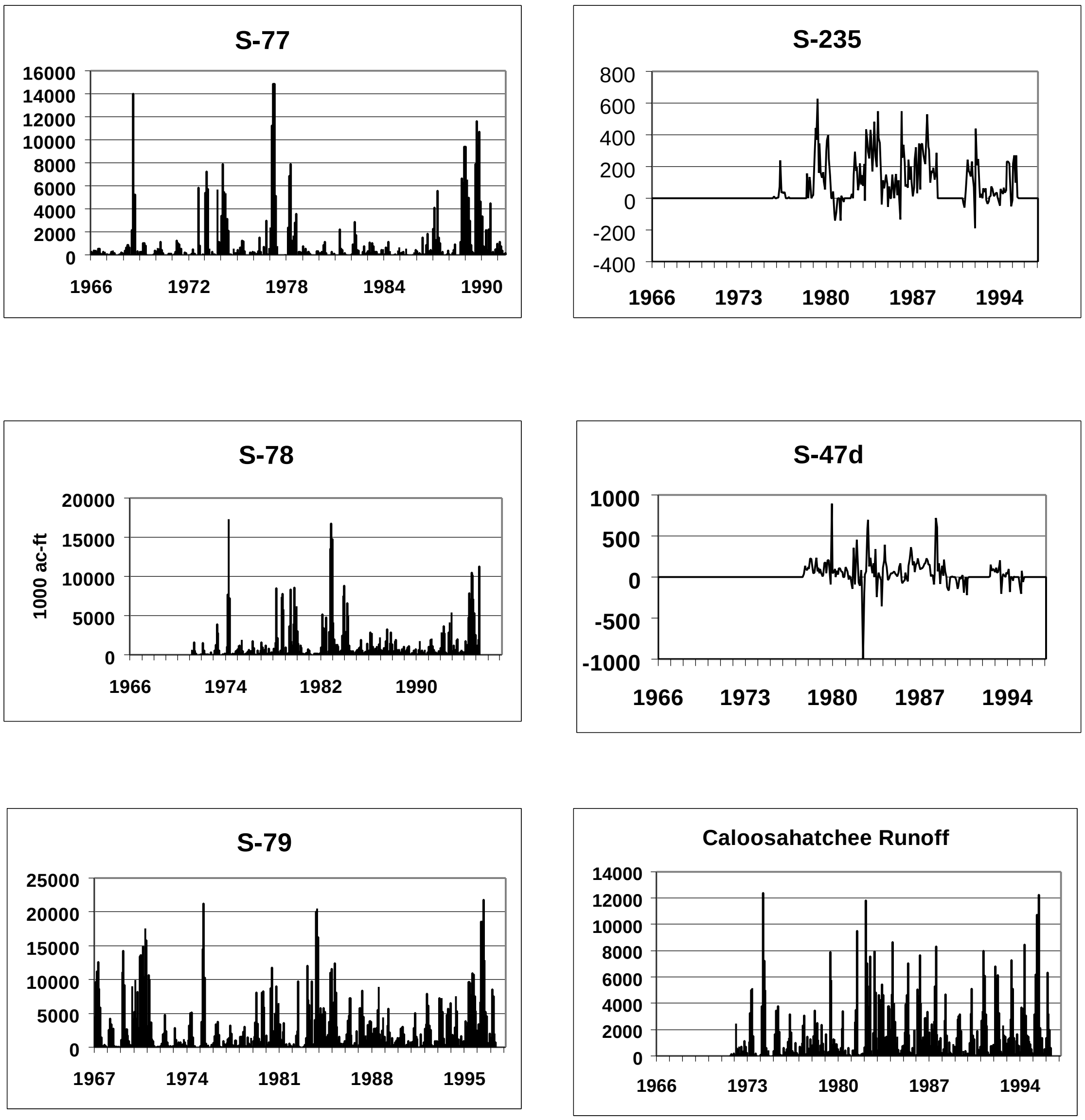


Fig. 13 Typical head data from shallow groundwater wells in the Caloosahatchee Watershed for May 1994.

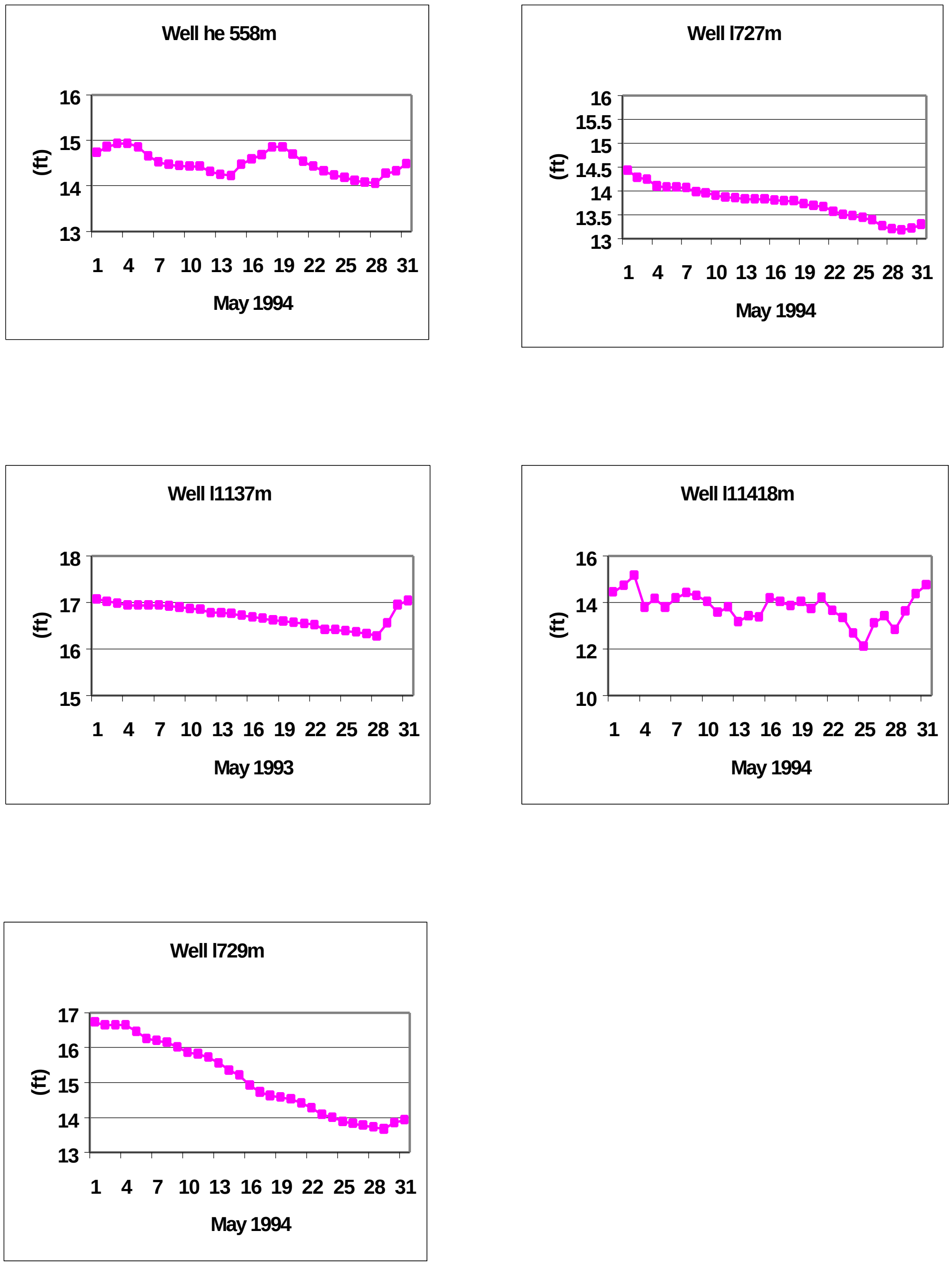


Fig. 13 Typical head data from deep groundwater wells in the Caloosahatchee Watershed for May 1994.

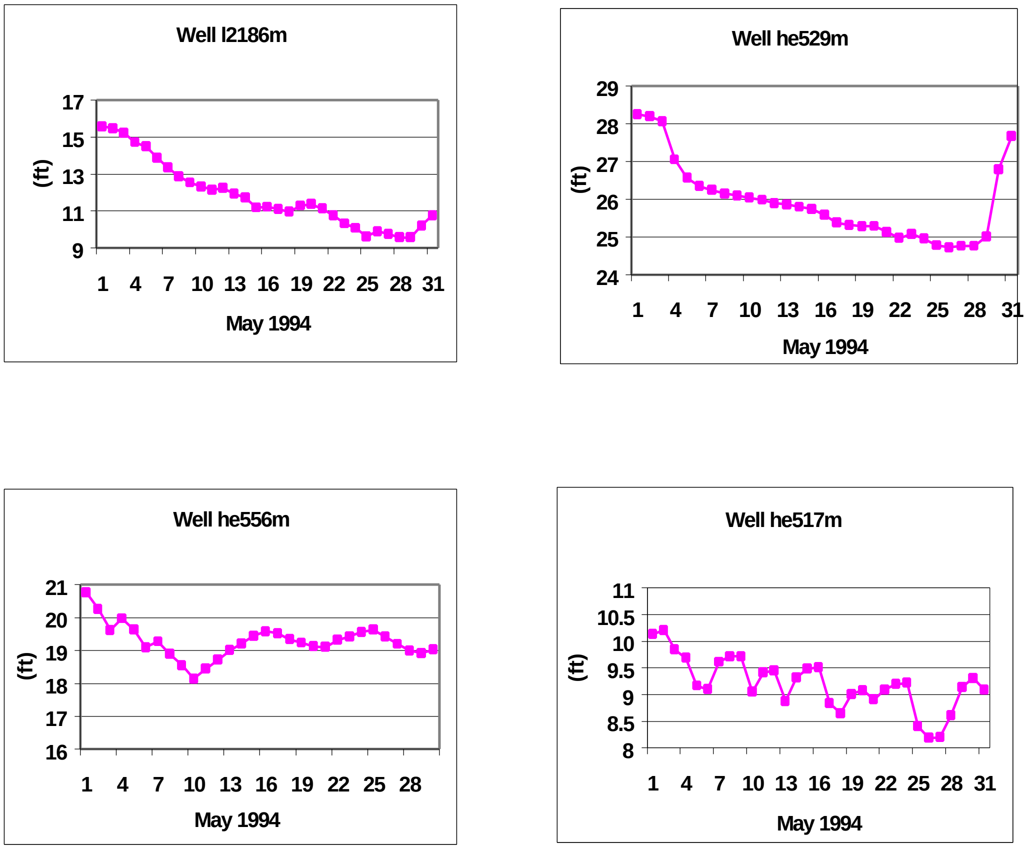


Fig.14 Groundwater Stage For Period of Record For SFWMD Ambient Monitoring Wells

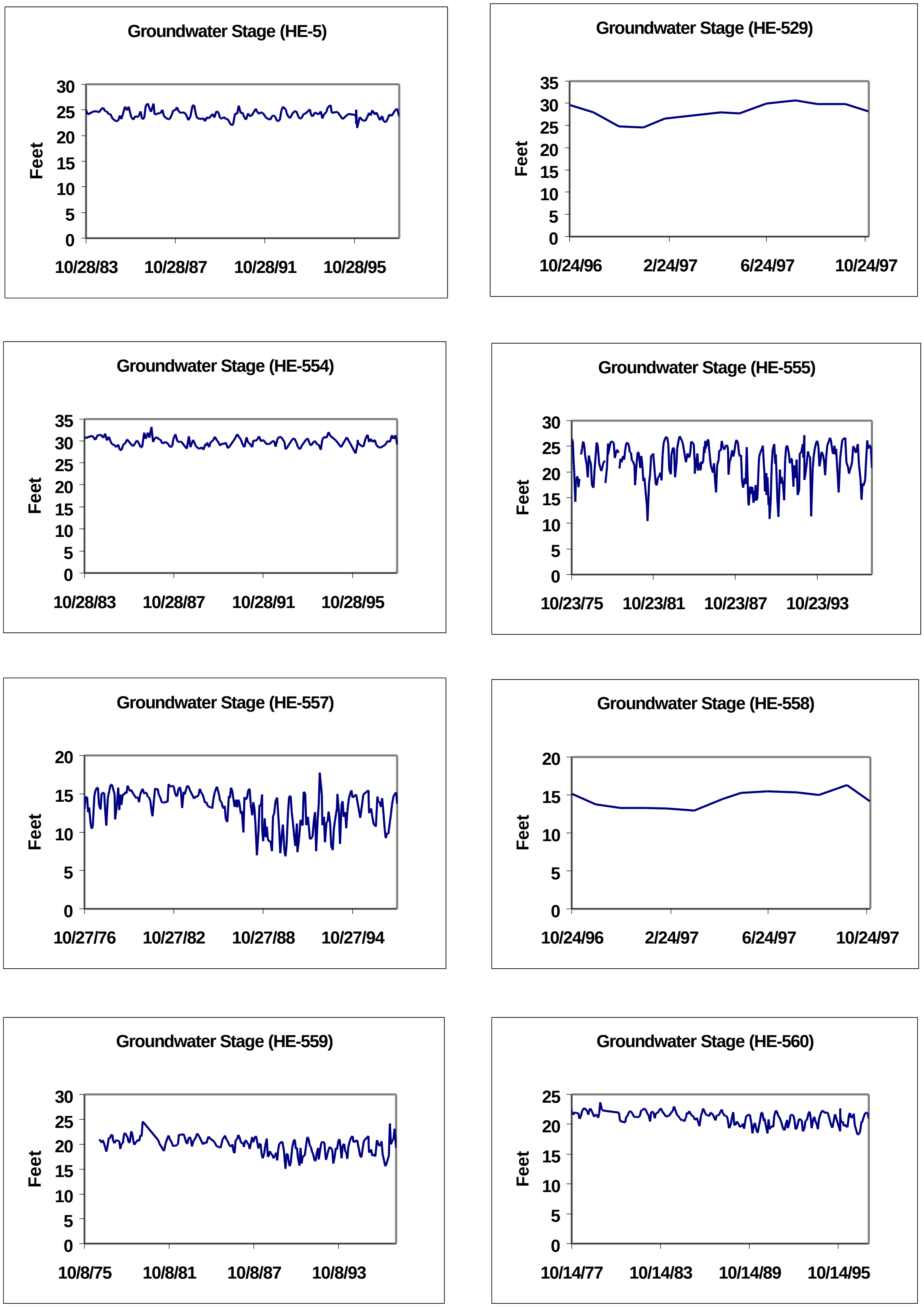
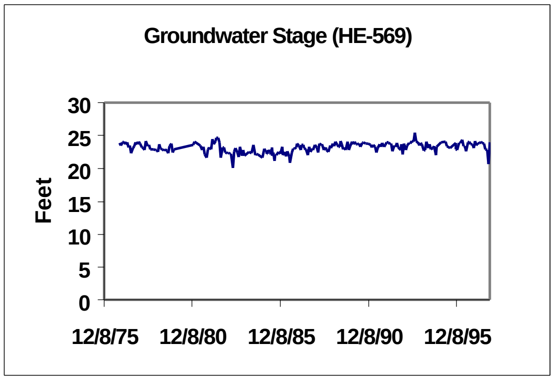
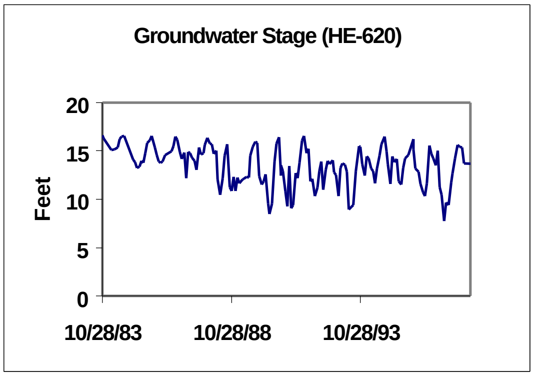


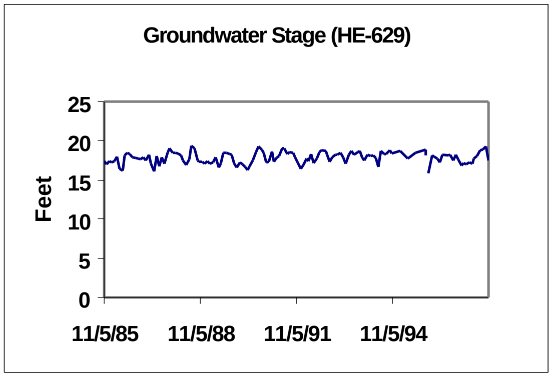
Table 7. Active groundwater wells in the Caloosahatchee Watershed.

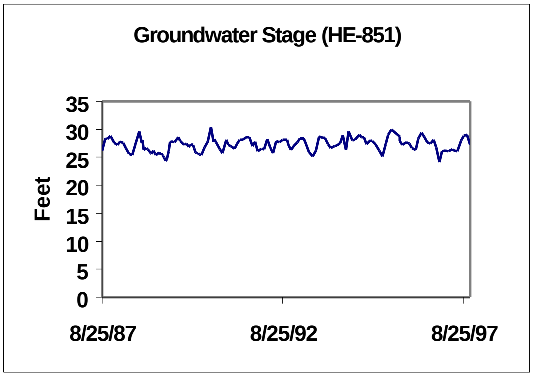
	Well	Basin	Depth (ft)	Casing Depth (ft)	Start Year
1	HE-517	West Caloosahatchee	158	135	1977
2	HE-529	West Caloosahatchee	155	135	1976
3	HE-556	West Caloosahatchee	155	135	1976
4	HE-558	West Caloosahatchee	13	3	1977
5	L-1137	West Caloosahatchee	20	15	1973
6	L-727	West Caloosahatchee	71	67	1973
7	L-729	Orange River	103	81	1977
8	L-1418	Orange River	62	55	1973
9	L-2186	Orange River	160	133	1977
10	HE-1075	East Caloosahatchee	155	135	1987
11	HE-529	West Caloosahatchee	155	135	1987
12	HE-554	West Caloosahatchee	15	5	1983
13	HE-1027	East Caloosahatchee	7	4	1987
14	HE-1028	East Caloosahatchee	60	20	1987
15	HE-1029	East Caloosahatchee	182	92	1987
16	HE-852	East Caloosahatchee	14	9	1986
17	HE-853	East Caloosahatchee	61	17	1986
18	HE-5	East Caloosahatchee	13	8.7	1983
19	HE-1076	East Caloosahatchee	340	300	1988
20	HE-1077	East Caloosahatchee	10	5	1988
21	HE-555	West Caloosahatchee	270	250	1975
22	HE-851	West Caloosahatchee	13	5	1987
23	HE-559	West Caloosahatchee	165	155	1975
24	HE-560	West Caloosahatchee	80	70	1977
25	HE-569	West Caloosahatchee	17	11	1975
26	HE-1068	Flagpole	160	60	1987
27	HE-1069	Flagpole	13	3	1987
28	HE-629	Flagpole	144	133	1985
29	HE-858	East Caloosahatchee	17	12	1986
30	HE-557	West Caloosahatchee	100	80	1976
31	HE-558	West Caloosahatchee	13	3	1996
32	HE-620	West Caloosahatchee	350	171	1983
33	HE-857	East Caloosahatchee	17	12	1977
34	HE-516	West Caloosahatchee	273	270	1986

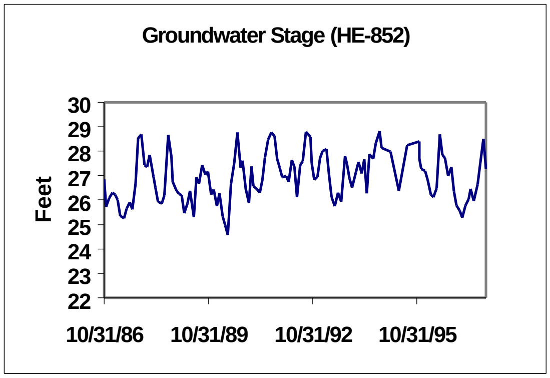
Fig.14 Groundwater Stage For Period of Record For SFWMD Ambient Monitoring Wells

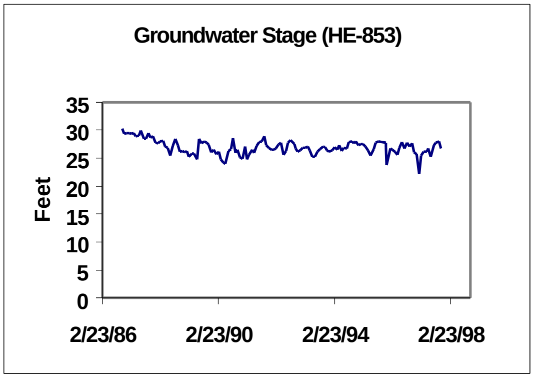


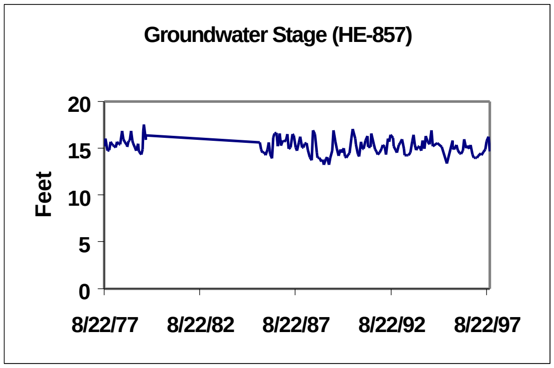












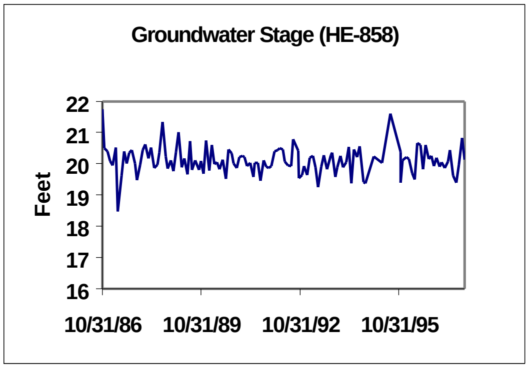
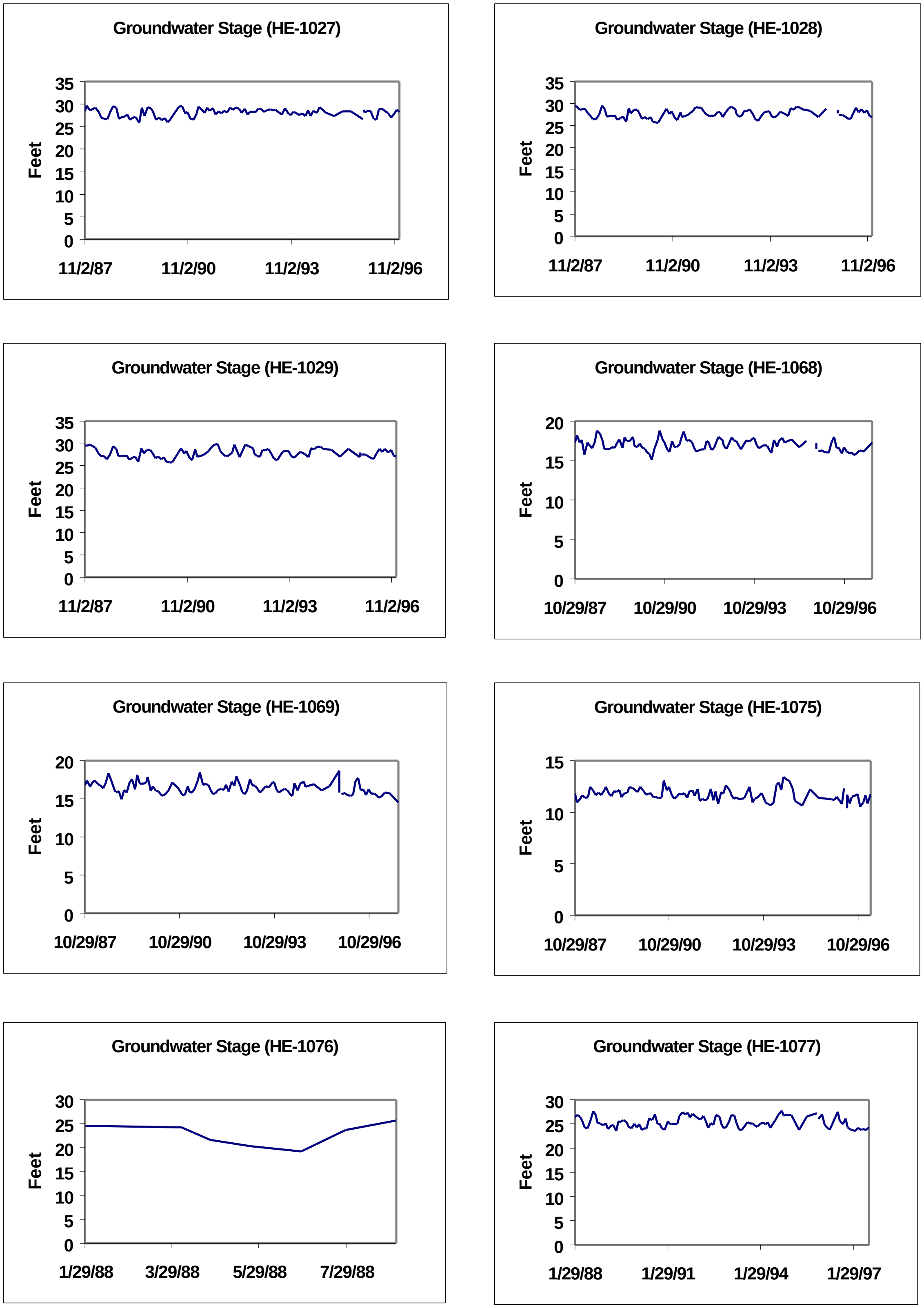


Fig.14 Groundwater Stage For Period of Record For SFWMD Ambient Monitoring Wells



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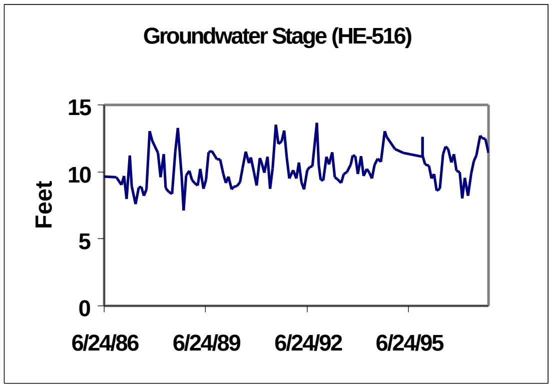

3.5 Water Supply

Pumpage data for water supply were obtained from growers for some of the water use permits through the Regulation Department at SFWMD. The pumpage data were reported as total monthly values for the period from 1993 to present. These data are available for 130 permits in the watershed. There are 97 permits that obtain water from the Caloosahatchee River. Of these permits, 35 have submitted pumpage reports to the SFWMD. The quality of the data ranges from estimated monthly values to total monthly water use to summation of actual daily water use. The quality of the individual records has not been assessed. Unfortunately, it was not possible to obtain a complete set of records for evaluation at this time.

3.6 Water Control District Hydrologic Data.

An attempt was made to obtain hydrologic data from the fourteen water control districts (WCDs) in the watershed. Hydrologic data were available only for the East County Water Control District (ECWCD). Hydrologic data for other WCDs may be available through the SFWMD, but effective retrieval was not possible. The ECWCD hydrologic data consists of stage at selected control structures in the three major basins (Table 8). The ECWCD also monitors stage is several canals. Canal stage data collection began in 1995 while canal stage at weirs began in 1985. These data will be used to evaluate the efficacy of weir head manipulation on local water storage and control of downstream flooding.

Table 8. Monitored weirs in East County Water Control District.

	Orange River	Hickey Creek	Bedman Creek
1	S-A-1	S-HC-I	S-D-1
2	S-A-2	S-M-I	S-H-1
3	S-NM-1	S-HC-2	S-H-3
4	S-OR-I-SE	S-A-2	S-LB-1
5	S-OR-I	S51-I-2	S57-24-2
6	S-R-I	S-H-3	S-LJ-1
7	S-SF-I		S-LD-1
8	S-SF-2		S57-1-2
9	S-YT-I		S57-12-1
10	S-ML-1B		S57-13-1
11	S-ML-1A		S57-24-2
12	S-ML-2		
13	S-ML-4		

4. DISCUSSION

The data collected during this task primarily came from the SFWMD. A few of the datasets came from NOAA and private companies. Most of the data from SFWMD were obtained through the standard SFWMD databases. As such, these data have been scrutinized for errors and aberrations. The flow data for the major structures on C-43 have been evaluated by USGS. A series of discharge measurements were made at each of the structures (S77, S78 & S79) using the acoustic doppler current profiler. The measurements were used to develop rating curves for each structure. An analysis of the rating curves has been developed by USGS; they compared the actual discharge to the values estimated by the rating curve. The results indicate that the relative error in discharge is less than 10% from 50 to 90% of the time at S77 and S79. The relative error at S79 is greatest at discharge less than 1000 cfs. Overall the rating at S79 is considered excellent. At S77, the relative error is less than 10% 80% of the time. The relative error is greater than 10% 70% of the time when flows are below 750 cfs. The rating at S77 is very good at large flow and poor at low flows. The rating analysis for S78 has not been completed.

The data from the permit pumpage files have not been checked and those data are not included in this report. The data from ECWMD appear to be reasonable and are readily available. There were not other data currently available that required review a part of this task deliverable.

There have been few hydrologic assessments in the Caloosahatchee Watershed. In particular, a study of tributary discharge was conducted as part of the analysis of the Caloosahatchee Watershed in the Miller et al. (1982) study of water quality in the Caloosahatchee River. Unfortunately the tributary flow data from that project has been lost, and it require additional labor beyond the scope of this project to place that data into the data base.

One intent of this task was to convert the available weather data into input datasets suitable for hydrologic simulation modeling. It was found that there were insufficient hydrometerological data available in the watershed to support standard hydrologic models. Each of the more powerful hydrologic models require weather data for estimating ET. Unfortunately, there are no long-term weather records of sufficient detail for conducting hydrologic simulations. For long-term simulation it will be necessary to adapt the ET estimates from the lower east coast data which are based on meterological data collected at West Palm Beach.

It was expected that a specific model would have been selected for hydrologic simulation. There has been no agreement as to the appropriateness of any specific model for simulating the hydrologic behavior of the watershed. No attempt has been made to convert these data into a dataset to support a specific model.

The hydrologic data have been summarized in this report and the provided on the Southwest Florida Research and Education Center Website. The datasets are available as ASCII files and Excel spreadsheets. Although it was intended that these data be developed into a relational database, there has been no agreement among the many potential users concerning the structure or content of the database, nor has there been agreement on the appropriate software. The recommendation has been to develop a simple, generic database that provides the available data in the most convenient format.

5. REFERENCES

Miller, T.H., A.C. Federico, and J.F. Milleson. 1982. A survey of water quality characteristics and Chlorophyll a concentrations in the Caloosahatchee River system, Florida. Tech. Pub. 82-4. South Florida Water Management District. West Palm Beach, FL.